A Community Outreach Lead Screening Program Using Capillary Blood Collected on Filter Paper

Teresa G. Holtrop, MD; Hugh Y. Yee, PhD; Pippa M. Simpson, PhD; Ralph E. Kauffman, MD

Objective: To test whether a method of fingerstick blood sample collection onto filter paper could be used as an alternative screening method in the field in settings where environmental lead contamination is a high risk.

Method: Members of the Pediatric Mobile Team of Children’s Hospital of Michigan, Detroit, collected paired venous and capillary blood samples from 120 children, aged 6 months to 6 years, who presented for services at any of 7 sites located in decaying neighborhoods of older sections of Detroit. All samples were analyzed for lead content by graphite furnace atomic absorption spectrometry.

Results: When filter paper samples with blood lead levels of 0.48 µmol/L (10 µg/dL) or higher were compared with matched venous samples, the concordance coefficient was 0.96. The sensitivity and specificity of the filter paper samples relative to the venous samples for a cutoff of 0.48 µmol/L (10 µg/dL) or higher were 94% and 99%, respectively, with a positive predictive value of 97%. However, at a cutoff of 0.72 µmol/L (15 µg/dL), the sensitivity and specificity dropped to 75% and 98%, respectively, with filter paper samples underreporting blood lead values. At any cutoff point (0.48, 0.72, or 0.96 µmol/L [10, 15, or 20 µg/dL]), the filter paper method was highly specific for lead.

Conclusions: Capillary filter paper sampling is an accurate and practical alternative to venous sampling for blood lead screening using 0.48 µmol/L (10 µg/dL) as the cutoff. The filter paper method predicts levels of 0.72 µmol/L (15 µg/dL) or higher less well. The cause of divergent values above 0.72 µmol/L (15 µg/dL) is not clear. Environmental contamination of capillary filter paper, however, does not seem to be an explanation.


AVERAGE BLOOD lead levels decreased in young children in this country between 1976 and 1991.1 However, there is still a population of low-income, mostly minority children living in decaying inner-city neighborhoods who continue to have an increased exposure to lead contamination.2,4 Many of these children fail to receive regular preventive medical care owing to the social disruption in their families and neighborhoods.3 Thus, they are not screened for blood lead levels on a regular basis, if at all.3

The Centers for Disease Control and Prevention (CDC) issued a revised statement on preventing lead poisoning in young children in 1991.6 It emphasized the need for continued development of a low-cost, easy-to-use portable blood lead screening device as one approach to resolving this problem. Capillary blood collection into tubes, while easy to do, carries with it problems of clotting and breakage. Some have attempted to use a fingerstick and filter paper method to collect blood for lead level analysis, but early attempts to do so led to unreliable results.7-12 A recent study of a new method of analyzing fingerstick blood collected on filter paper seemed to offer promise that such a method could be useful in the field.13 However, that study was done in a hospital setting, while collection in neighborhood sites is frequently carried out in the presence of an environment that may be contaminated with lead. We decided to test the reliability of this newer method in the field in neighborhoods of Detroit, Mich, marked by old, frame, largely decaying housing.
SUBJECTS AND METHODS

SUBJECTS

Children aged 6 months to 6 years who were seen by the Children's Hospital Pediatric Mobile Team, Detroit, were eligible for inclusion in the study. Recruitment of patients was done from November 1994 through October 1995. Written informed consent was obtained from a parent. The protocol used was approved by the Pediatric Committee of the Wayne State University Institutional Review Board, Detroit.

SETTING

The Pediatric Mobile Team conducts its clinical activities in buildings provided by hosting organizations in the local community. These sites are very similar to typical screening sites that a public health department might use when conducting community outreach sessions, such as neighborhood recreation/multiservice sites (3 sites), drug treatment centers (2 sites), a day-care program (1 site), and a church (1 site). Six of the 7 sites in which blood collections were made are located on Detroit's east side, in an area marked by old deteriorating housing and a high incidence of lead poisoning. The seventh site was located in central Detroit on the Detroit Medical Center Campus in a building dating from the 1920s. Only 2 of the sites had been built after the laws eliminating lead from paint had been passed. The other site buildings were built in the 1920s, 1940s, 1957, 1964, and 1975, respectively. Thus, the potential for environmental lead contamination of samples from lead-containing dust was relatively high.

SAMPLE COLLECTION

A Pediatric Mobile Team staff member, either a medical assistant or a resident or attending physician, collected the samples. Staff had received approximately 20 to 30 minutes of training in the filter paper blood collection technique. Each patient's hands and fingers were thoroughly scrubbed with soap and water for a minimum of 15 seconds, rinsed with water, and dried with a paper towel. While covering the fingers from which blood was to be drawn with the last-used paper towel, the patient was led back to the sampling area where the third or fourth finger was firmly grasped, wiped with alcohol, and allowed to dry briefly. Using sterile disposable lancets, a finger prick was made using the standard capillary sampling protocol recommended by the CDC. The first droplet of blood was wiped off with a clean gauze. A well-beaded drop of blood was then dropped to the filter paper (903 paper, catalog #58370, Schleicher & Schuell Keene, NH) to approximately fill first one and then another ½-in-diameter circle. Care was taken not to superimpose drops of blood within the circles. Superimposed drops may clot, causing large errors. Blood was prevented from running down the side of the finger. Approximately 4 to 5 drops of well-beaded blood were needed to completely fill each circle. The filter paper was placed in a plastic bag, which was left unsealed until venous sampling was complete to let the blood dry briefly. Using standard phlebotomy technique, venous blood was drawn from either the antecubital fossa or the dorsum of the hand or wrist into lead-free EDTA-containing lavender tubes. Venous samples were placed in a separate plastic bag and stored in a refrigerated cooler for transport to the laboratory. Once venous sampling was complete, the plastic bag containing the filter paper sample was sealed and set aside for transport to the laboratory. Materials used for sample collection had previously been documented to be free of lead contamination.

SPECIMEN PROCESSING

Specimens were processed and analyzed in the Detroit Medical Center University Laboratory, using a graphite furnace atomic absorption spectrometric micromethod for both whole-blood and filter paper samples. This method is described in detail elsewhere.14,15 The method was slightly modified from that used previously13 by using only a single ½-in-diameter punched disk instead of 5 to 6 segments of a ½-in-diameter blood spot.15 The Detroit Medical Center University Laboratory is approved by the Occupational Safety and Health Administration for blood lead determinations and participates in the Blood Lead Laboratory Reference System through the CDC.

STATISTICAL ANALYSIS

The 2 methods of blood lead collection were compared using linear coefficients.14 The sensitivity, specificity, and predictive value of the filter paper method compared with the venous sampling reference method for blood lead levels was calculated for the intervention decision lead levels of 0.48, 0.72, and 0.96 µmol/L (10, 15, and 20 µg/dL), consistent with the CDC guidelines. For each of the 3 levels, sensitivity was calculated as the number of samples with values above the level by both methods (number of true-positive results detected) divided by the number detected above the level by the reference venous sampling method (true-positive plus false-negative results × 100). Similarly, specificity was calculated for each level as the number of samples no higher than the level by both methods (number of true-negative results detected) divided by the number detected below the decision level by the reference method (true-negative plus false-positive results × 100). Positive predictive value was computed as the number of true positives divided by the total number detected by the filter paper method.

RESULTS

We screened 165 infants and children for blood lead during the study period. Informed consent was obtained to enter 124 of these patients into the study. Four of these subjects were eliminated from the study because of failure to follow the protocol: in 2 cases venous blood could not be obtained and in the other 2 improper technique was used to obtain the venous sample. Thus, a total of 120 paired samples were obtained and analyzed for the study. Ninety-seven percent of the subjects were African American; the remaining subjects were white. There were more boys (59%) than girls (41%), but the sample was otherwise similar to the usual population seen in the

©1998 American Medical Association. All rights reserved.
clinics operated by our Mobile Team. We found there to be no difference in concordance between lead levels in filter paper and venous samples obtained by any one sampler when compared with the others.

We plotted the results of the analysis of venous blood samples against those of capillary samples and obtained the scattergram shown in the Figure. The concordance coefficient was 0.96. The Table shows the sensitivity, specificity, positive predictive value, and negative predictive value of capillary blood testing at 3 different decision levels when simultaneously obtained venous samples were used as the comparison group.

Thirty-one venous samples had values greater than or equal to the CDC cutoff of 0.48 µmol/L (10 µg/dL), resulting in a 26% prevalence of elevated blood lead levels. Elevated blood lead levels ranged from 0.48 µmol/L (10 µg/dL) to 2.32 µmol/L (48 µg/dL). Thirty capillary samples had blood lead levels of 0.48 µmol/L (10 µg/dL) or higher, with a range of 0.48 µmol/L (10 µg/dL) to 2.17 µmol/L (45 µg/dL).

There was only 1 false-positive filter paper result. This yielded a false-positive rate in our sample of 0.83%. The filter paper value in that case was 0.48 µmol/L (10 µg/dL) while the venous sampling value was only 0.34 µmol/L (7 µg/dL). There were 2 false-negative filter paper results, yielding a false-negative rate of 1.7%. Again, the actual values were very close: venous sampling vs filter paper levels were 0.48 µmol/L vs 0.43 µmol/L (10 µg/dL vs 9 µg/dL) and 0.53 µmol/L vs 0.39 µmol/L (11 µg/dL vs 8 µg/dL).

The preferred method of sampling for blood lead levels is venipuncture. However, successful venipuncture sampling in small children requires a high degree of phlebotomy skill. Alternative sampling techniques are welcomed by those interested in screening as many young children in high-risk areas as possible. Capillary finger-stick blood collected into microcontainers is the most common alternative method. However, problems with clotting and breakage of tubes persist. Filter paper sampling has the advantage of ease of collection but avoids problems of clotting after collection, can be stored for prolonged periods of time, and is easy to transport because samples can even be mailed in an envelope. Environmental contamination of filter paper, either before or after collection, has been a major concern. Our study confirms the finding of Srivuthana et al that this filter paper blood lead level sampling method performs well in identifying children who require further follow-up per CDC guidelines. Additionally, it does so when used for screening in community settings. Environmental lead contamination of filter paper did not present a problem for blood lead level screening when prescribed procedures were followed even in a community (nonclinic) setting.

<table>
<thead>
<tr>
<th>Blood Lead Level, µmol/L (µg/dL)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Positive Predictive Value (%)</th>
<th>Negative Predictive Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.48 (10) vs ≥0.48 (10)</td>
<td>94</td>
<td>99</td>
<td>97</td>
<td>98</td>
</tr>
<tr>
<td>&lt;0.72 (15) vs ≥0.72 (15)</td>
<td>75</td>
<td>98</td>
<td>86</td>
<td>96</td>
</tr>
<tr>
<td>&lt;0.96 (20) vs ≥0.96 (20)</td>
<td>78</td>
<td>100</td>
<td>100</td>
<td>98</td>
</tr>
</tbody>
</table>

*All values are given as percentage unless otherwise indicated.

COMMENT

The preferred method of sampling for blood lead levels is venipuncture. However, successful venipuncture sampling in small children requires a high degree of phlebotomy skill. Alternative sampling techniques are welcomed by those interested in screening as many young children in high-risk areas as possible. Capillary finger-stick blood collected into microcontainers is the most common alternative method. However, problems with clotting and breakage of tubes persist. Filter paper sampling has the advantage of ease of collection but avoids problems of clotting after collection, can be stored for prolonged periods of time, and is easy to transport because samples can even be mailed in an envelope. Environmental contamination of filter paper, either before or after collection, has been a major concern. Our study confirms the finding of Srivuthana et al that this filter paper blood lead level sampling method performs well in identifying children who require further follow-up per CDC guidelines. Additionally, it does so when used for screening in community settings. Environmental lead contamination of filter paper did not present a problem for blood lead level screening when prescribed procedures were followed even in a community (nonclinic) setting.
Five of the 7 sites where blood sampling was performed were older buildings with a high potential for environmental lead contamination. We did not test the tap water that was used to wash hands at each site for lead content. Despite these limitations, we did not observe any tendency toward elevated lead levels in the filter paper blood samples when compared with their paired venous samples.

While others have previously studied blood lead level sampling with filter paper,7-12 the report by Srivuthana et al13 is the only one to use the same method as our study. The concordance coefficient was reported to be 0.96. Sensitivity was 90%, 98% and 94% at cutoffs of 0.48, 0.72, and 0.96 µmol/L (10, 15, and 20 µg/dL), respectively. Positive predictive value was 93%, 98%, and 97% compared with our values of 96%, 83%, and 100%.

The positive predictive value for identifying children with a blood lead level of 0.48 µmol/L (10 µg/dL) or higher in our study sample was 96%. This means that if the filter paper blood lead level is 0.48 µmol/L (10 µg/dL) or higher, there is 96% probability that the value will be at least 0.48 µmol/L (10 µg/dL) on the paired venous sample. However, positive predictive value is very sensitive to the overall prevalence rate in the population screened and will be lower than 97% in a population with a substantially lower prevalence of elevated blood lead levels.

Our false-negative rate of 1.7% will be of concern to some. It is important to note that these false-negative results occurred at the very low end of the spectrum, where treatment would not necessarily be given. While missing patients with these levels might allow continued exposure to an environmental source of lead, it is worthwhile to think about that any variation in results caused by venous sampling laboratory error will cause a similar situation.

The trend we noted for filter paper blood lead level values to diverge downward as venous blood lead level values increased is another indication that filter paper sampling was not predisposed to external lead contamination. The reason for the drop in sensitivity at blood lead levels of 0.72 µmol/L (15 µg/dL) or higher is not clear. It is most likely a spurious finding caused by our limited number of samples with higher lead levels. Thorough handwashing before capillary blood collection and protection against contamination are the 2 most important activities to minimize lead contamination regardless of what type of capillary blood collection method is used. Thus, for this study, thorough handwashing and protection of the capillary puncture site were strictly followed.

The ease with which staff can be trained in the proper technique makes this sampling technique attractive in both private as well as public health care settings. We found that training required no more than 20 to 30 minutes. In all, 4 staff members collected the samples. Two were physicians and 2 were medical assistants. It was easy to monitor the quality of staff work by reviewing the concordance between venous and filter paper values.

In conclusion, the filter paper method for lead determination that we describe seems to have high sensitivity and specificity and correlates extremely well with venous sampling in a screening situation. The ease with which it can be performed and sent out to laboratories makes it an attractive alternative to other microtechniques for whole-blood lead level sampling.

Accepted for publication December 1, 1997.
Presented at the annual meeting of the Society for Pediatric Research, Washington, DC, May 7, 1996.
Special thanks to Sanford Cohen, MD, for reviewing the manuscript and for his many helpful suggestions. We are also grateful to Satish Khanzode, MD; Marcia Wilson, MA; Deidre Sims, MA; and Stacy Thompson for their assistance in collecting lead samples.

Reprints: Teresa Holtrop, MD, Ambulatory Pediatrics, Children’s Hospital of Michigan, 3901 Beaubien, Detroit, MI 48201.

REFERENCES

Error in Figure. In the article titled “A Community Outreach Lead Screening Program Using Capillary Blood Collected on Filter Paper” published in the May issue of the ARCHIVES (1998;152:455-458), the Figure was reproduced incorrectly. The correct figure is shown below. The journal regrets the error.